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(54) **SHEARABLE SPLIT BALL SEAT**

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E21B 34/06 (2006.01)
E21B 23/00 (2006.01)
E21B 23/04 (2006.01)
E21B 33/00 (2006.01)
E21B 43/26 (2006.01)

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CPC ***E21B 34/142*** (2020.05); ***E21B 23/006*** (2013.01); ***E21B 23/0413*** (2020.05); ***E21B 33/00*** (2013.01); ***E21B 34/063*** (2013.01); ***E21B 34/14*** (2013.01); *E21B 43/26* (2013.01); *E21B 2200/04* (2020.05); *E21B 2200/06* (2020.05)

(58) **Field of Classification Search**

CPC E21B 34/14; E21B 24/142; E21B 23/006; E21B 23/0413; E21B 2200/06; E21B 222/04; E21B 29/00; E21B 33/00; E21B 33/14; E21B 34/063; E21B 23/03; E21B 34/142

See application file for complete search history.

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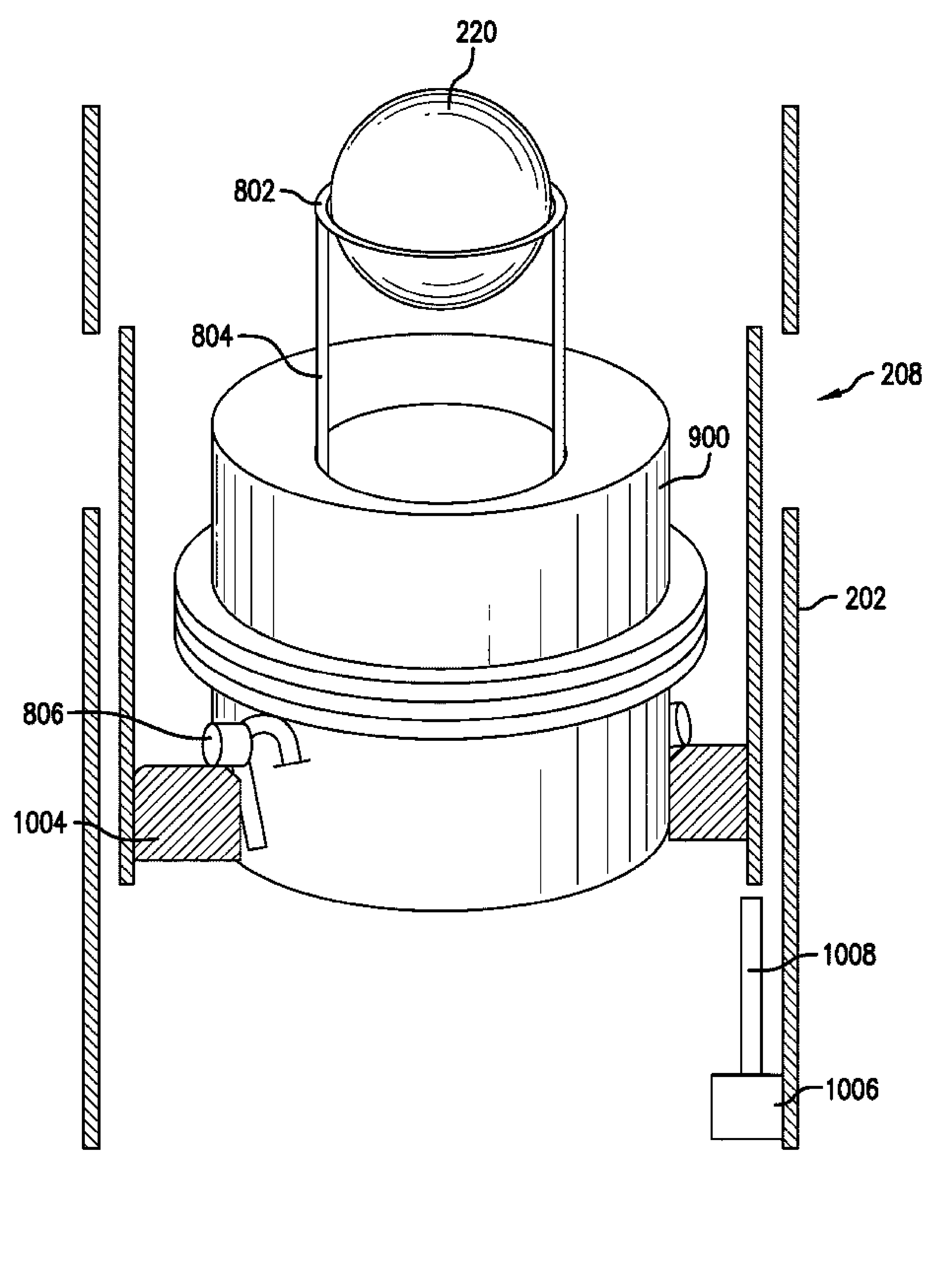
(57) **ABSTRACT**

A frac sleeve assembly and method of operation. The frac sleeve assembly includes a ball seat that retains a frac ball. The ball seat moves within a sleeve. The sleeve includes a profile that separates the first half and the second half to allow passage of the frac ball through the ball seat when the ball seat moves within the sleeve. Alternatively, the ball seat has a ring for receiving the frac ball and the sleeve has a protrusion that selectively engages a shifting pin to move the ring with respect to a ridge to release the ball from the ball seat when the ball seat moves within the sleeve.

5 Claims, 11 Drawing Sheets



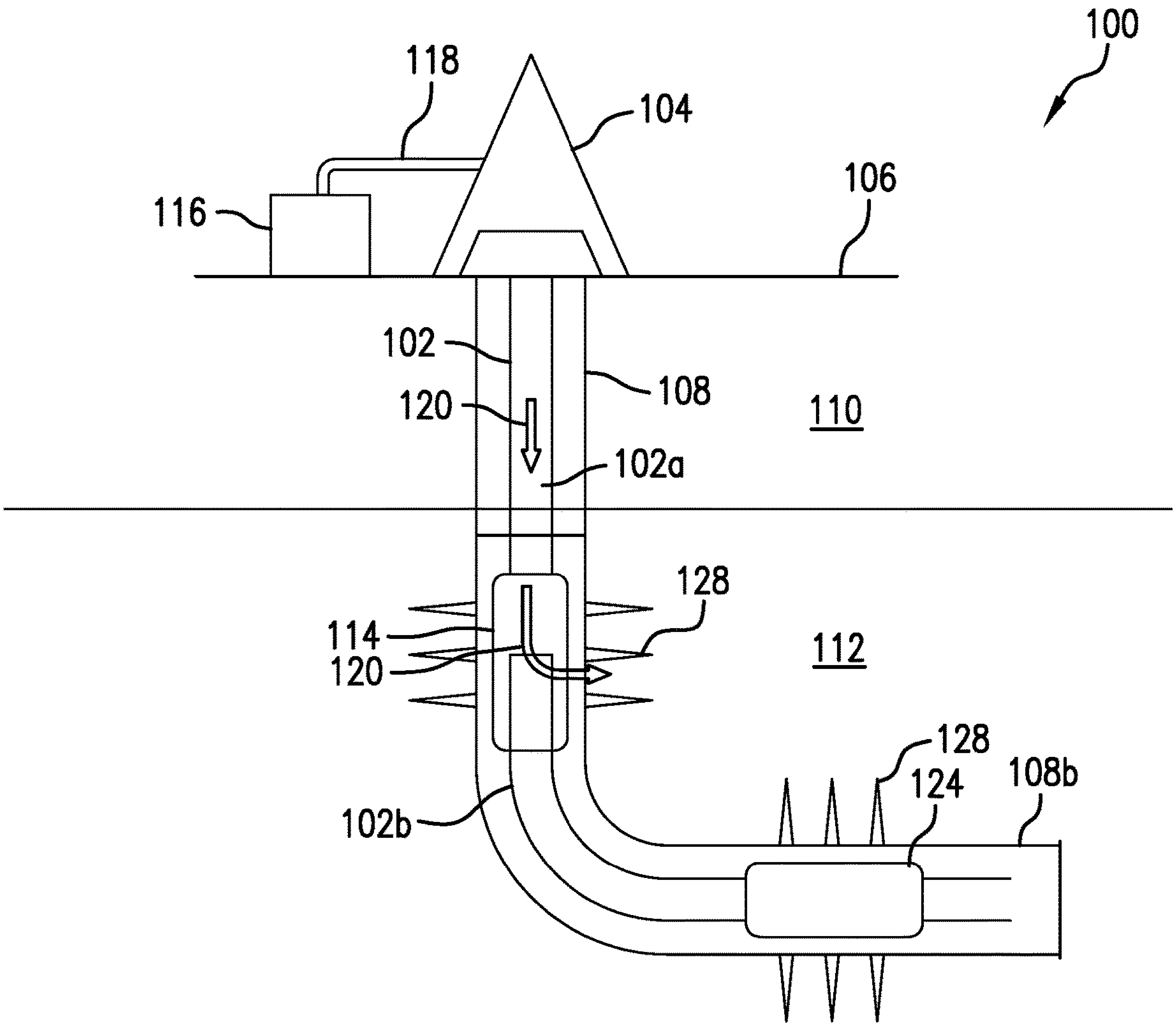

100
118
104
106
116
102
108
120
110
102a
128
114
120
112
128
124
108b
102b

FIG.1

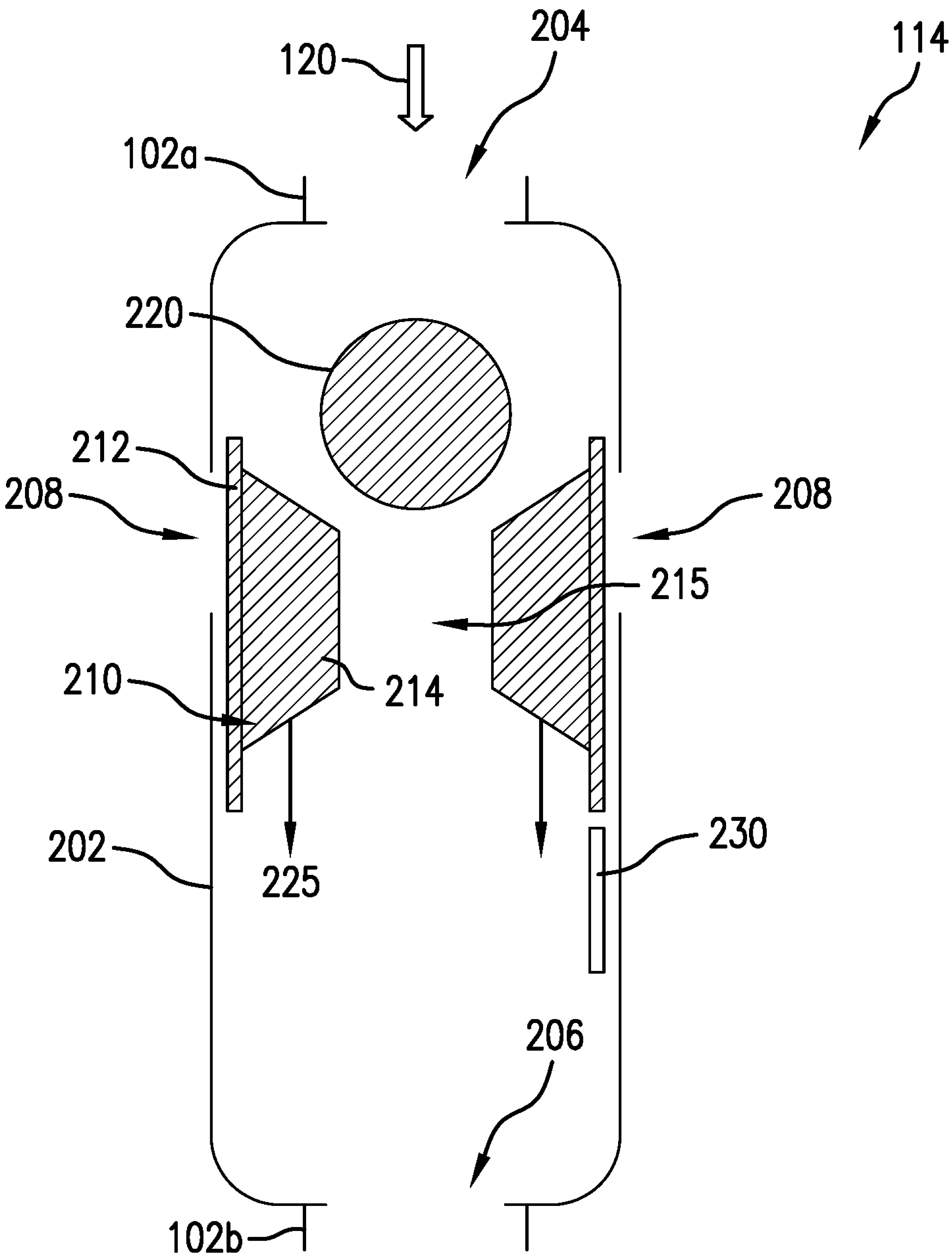

120
204
114
102a
220
212
208
208
215
210
214
202
225
230
206
102b

FIG.2

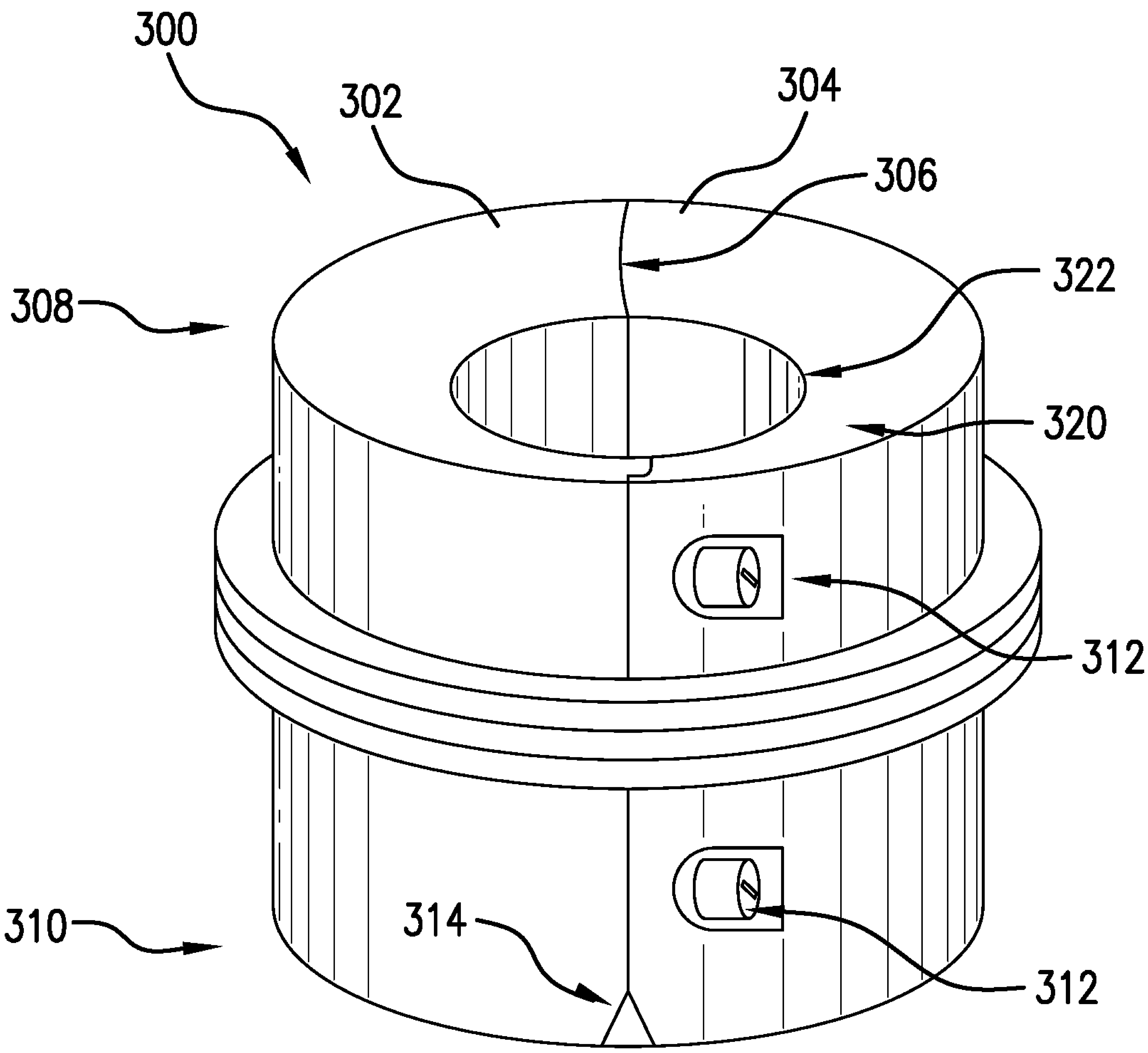


FIG.3

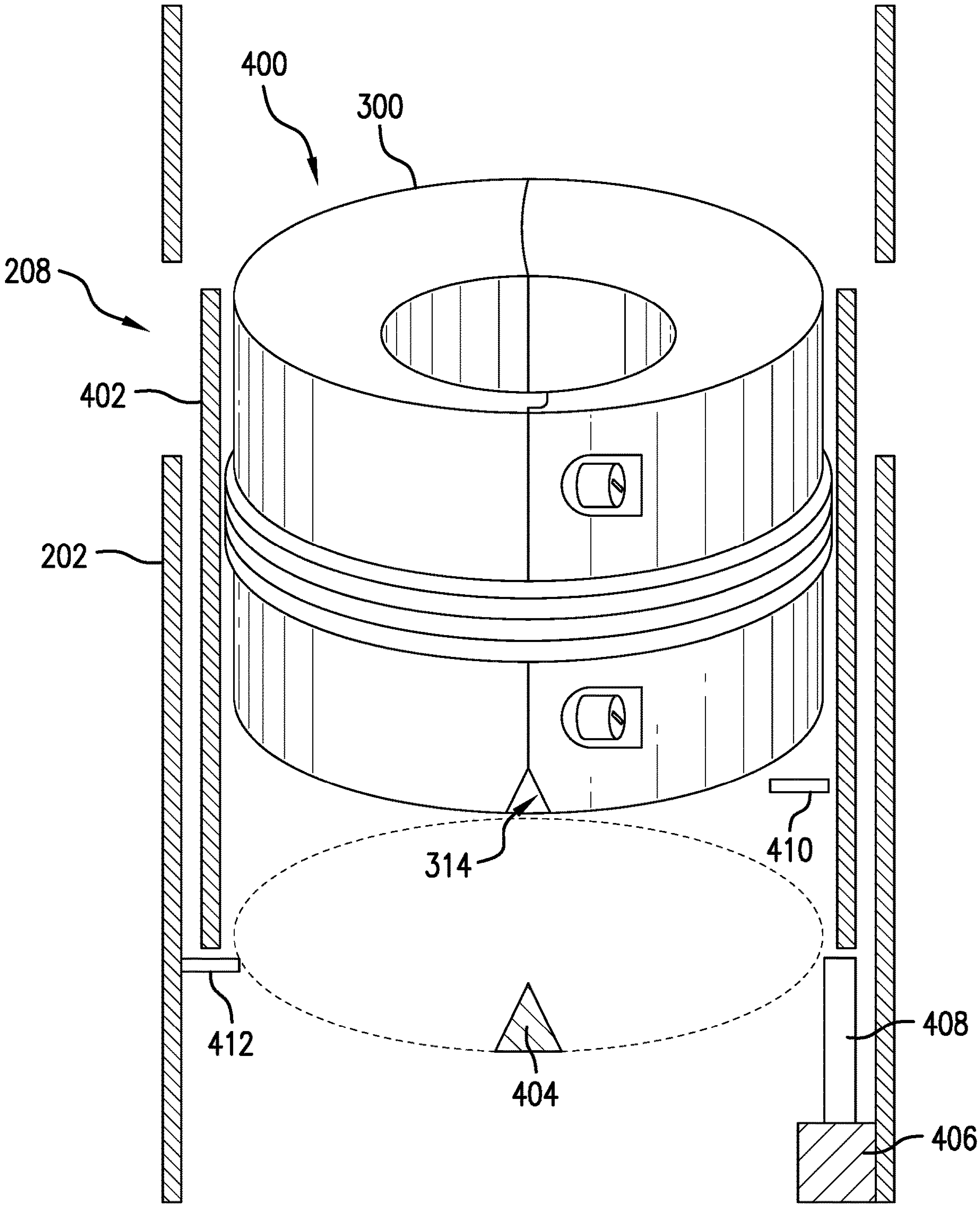


FIG.4

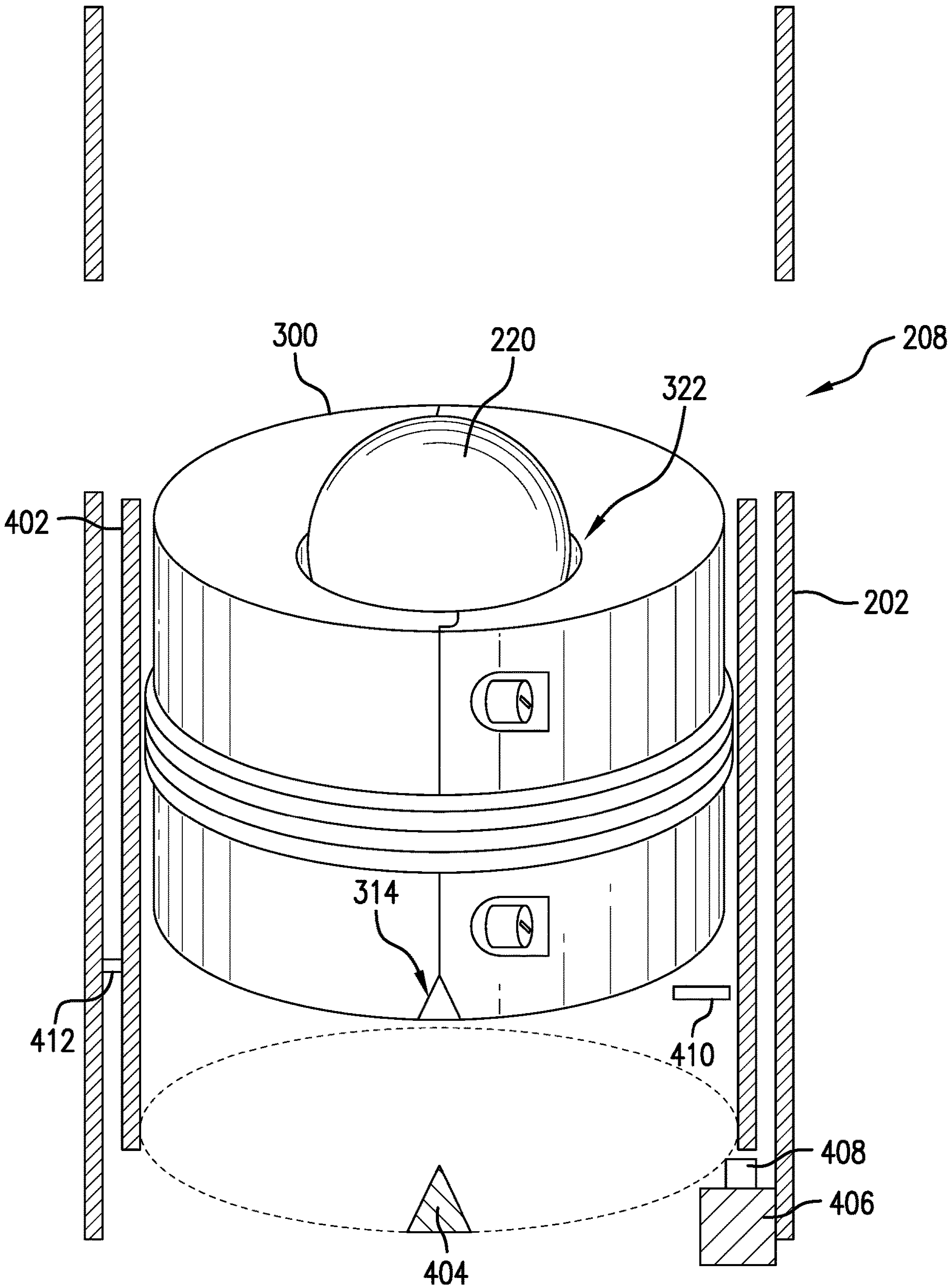


FIG.5

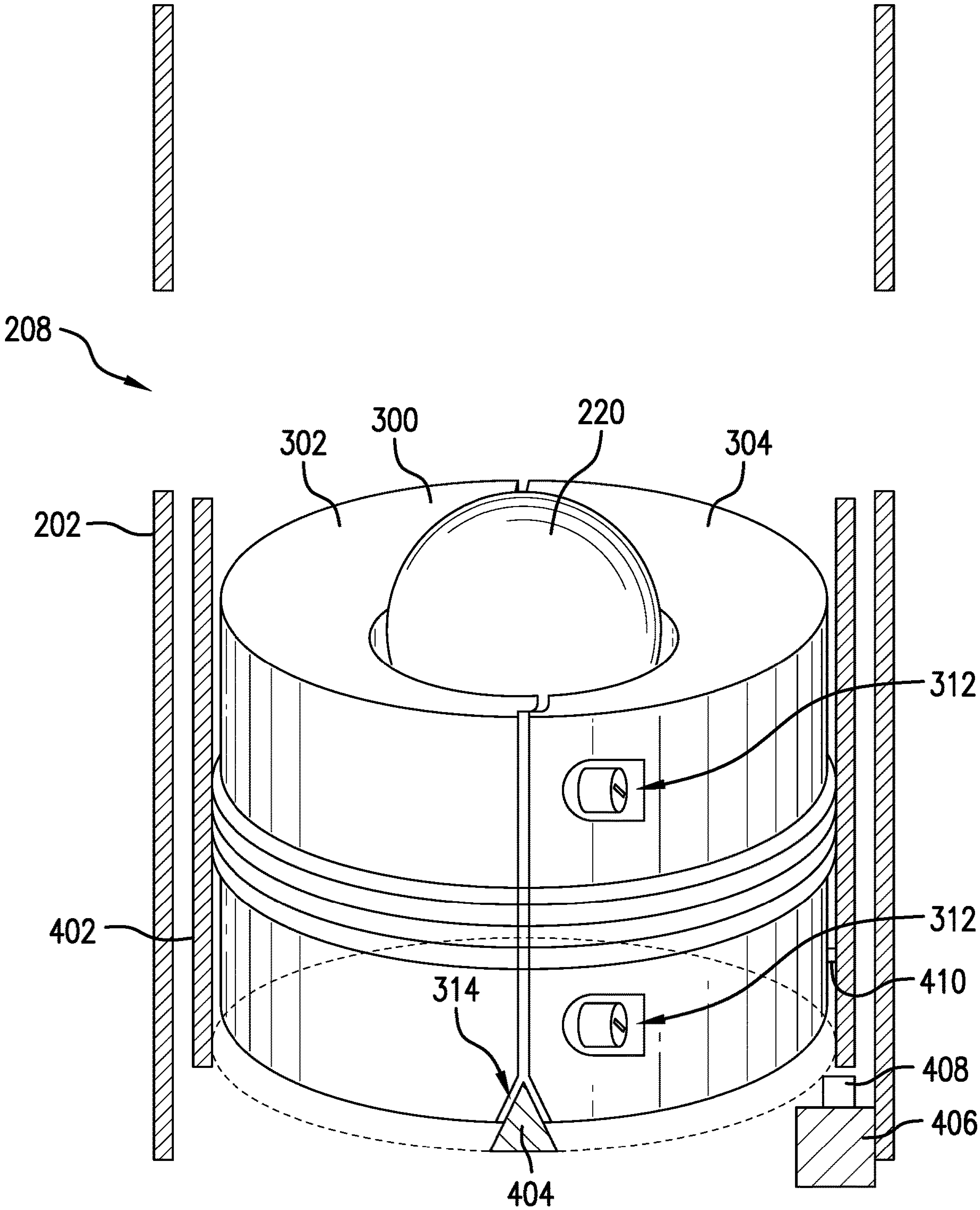


FIG.6

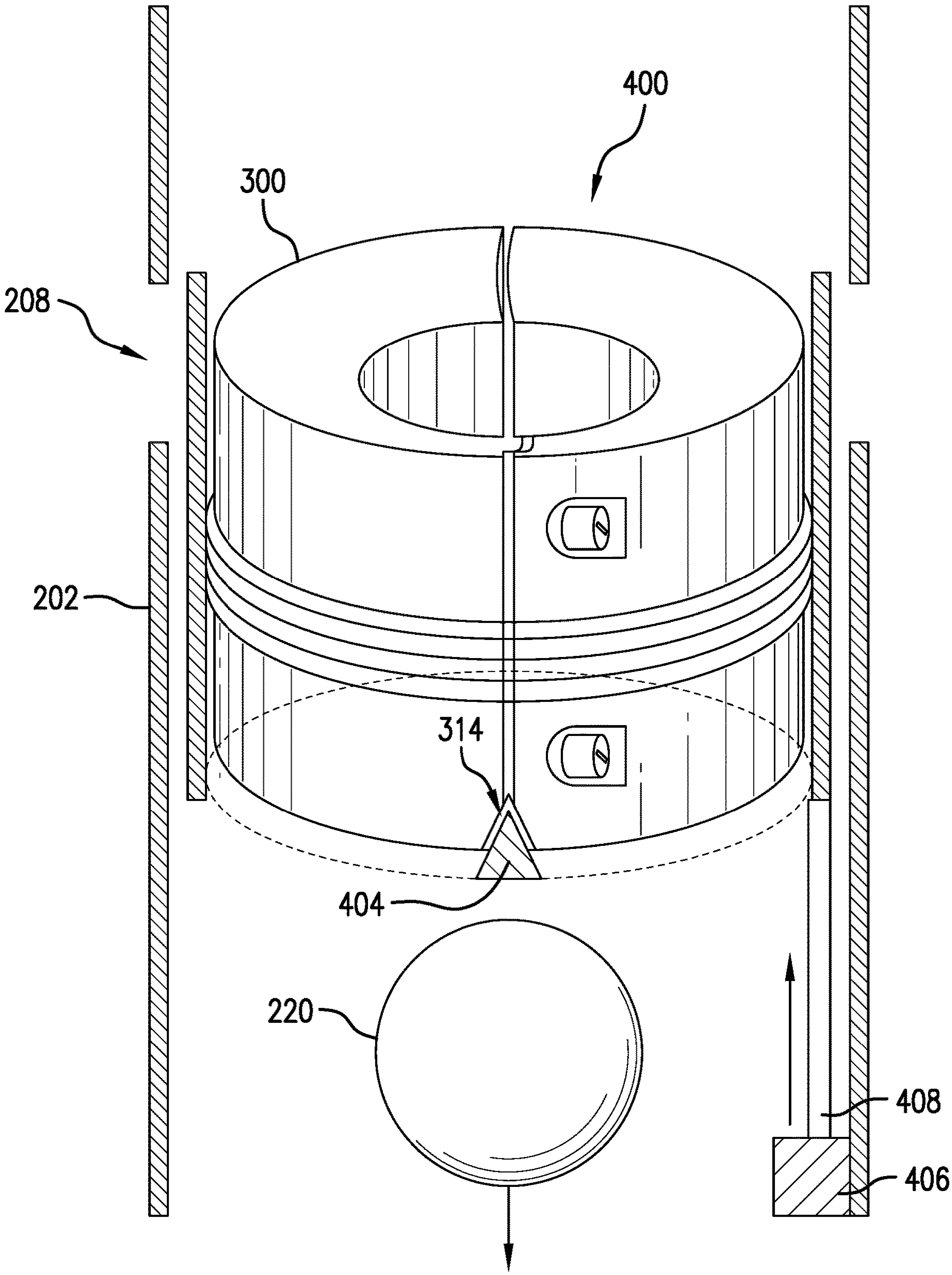


FIG.7

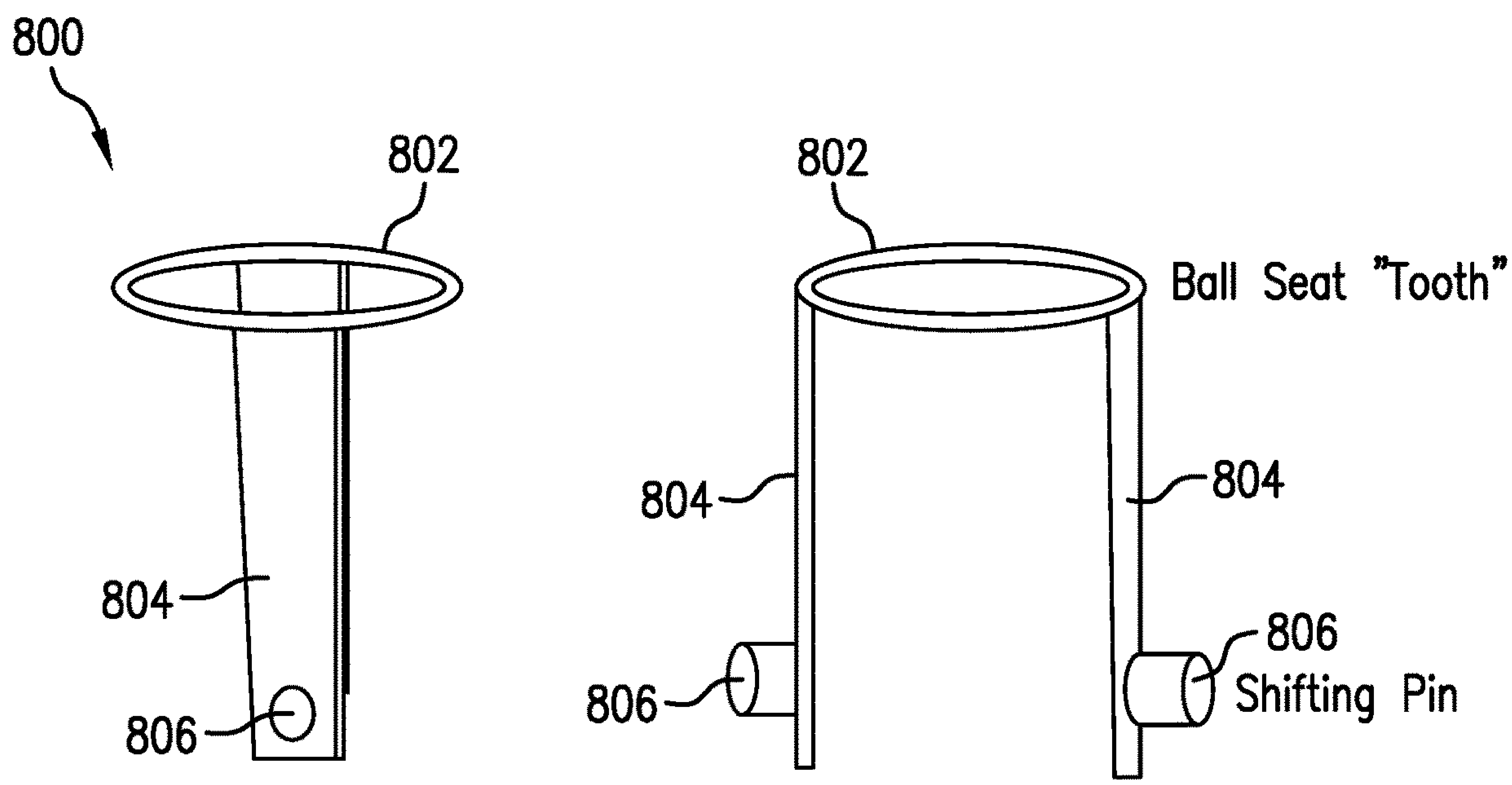

800
802
802
Ball Seat "Tooth"
804
804
804
806
806
806
Shifting Pin

FIG.8

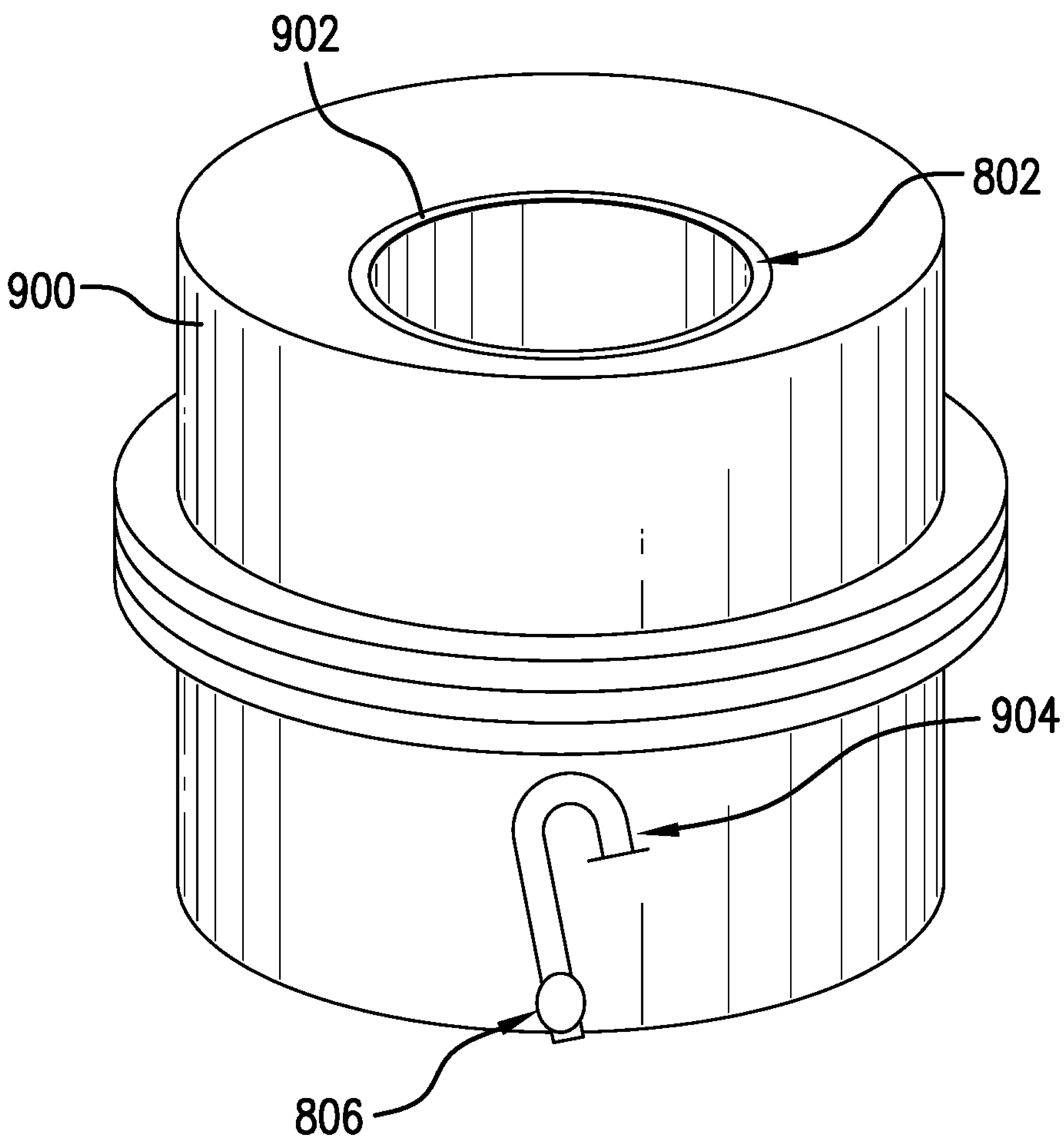


FIG.9

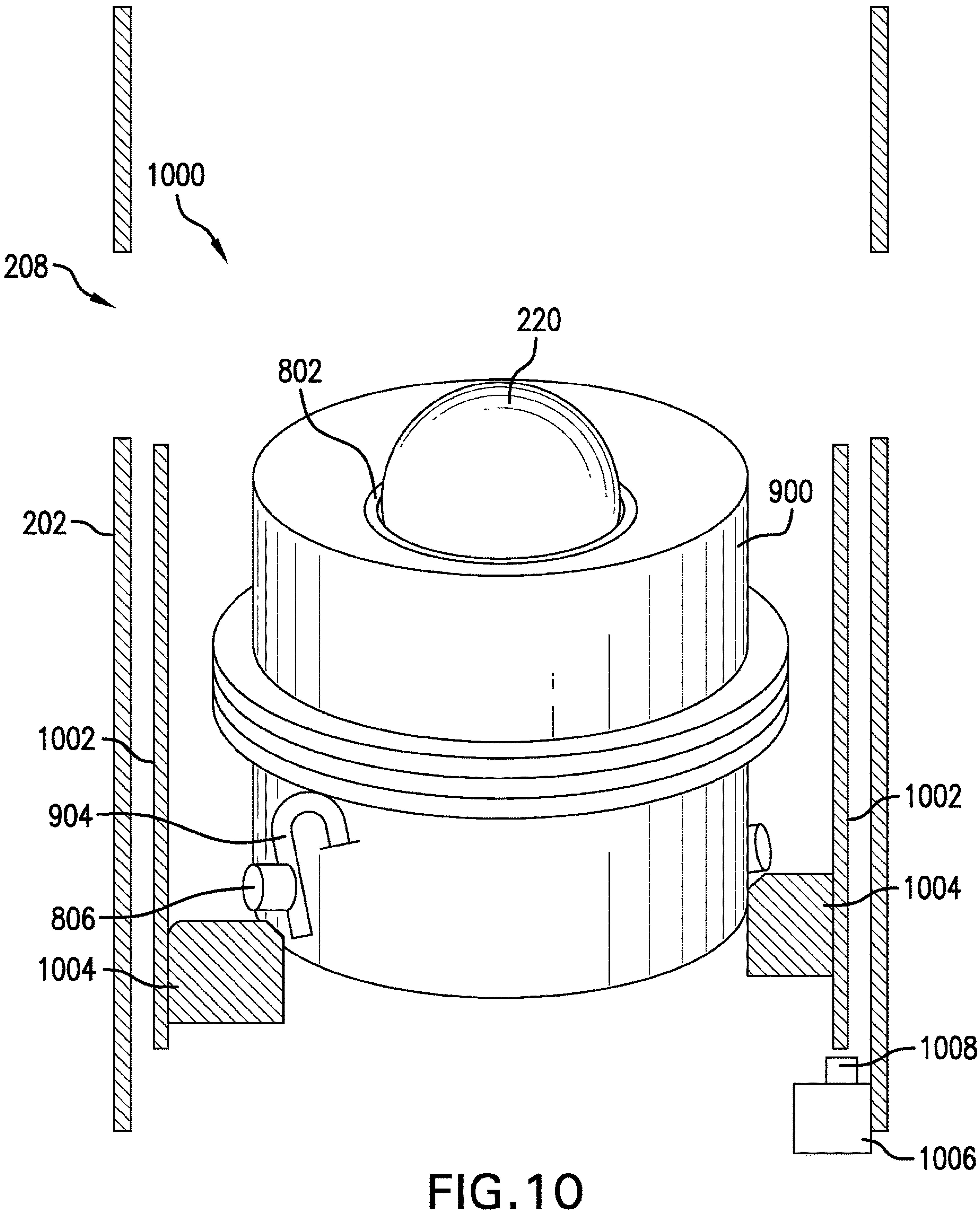


FIG. 10

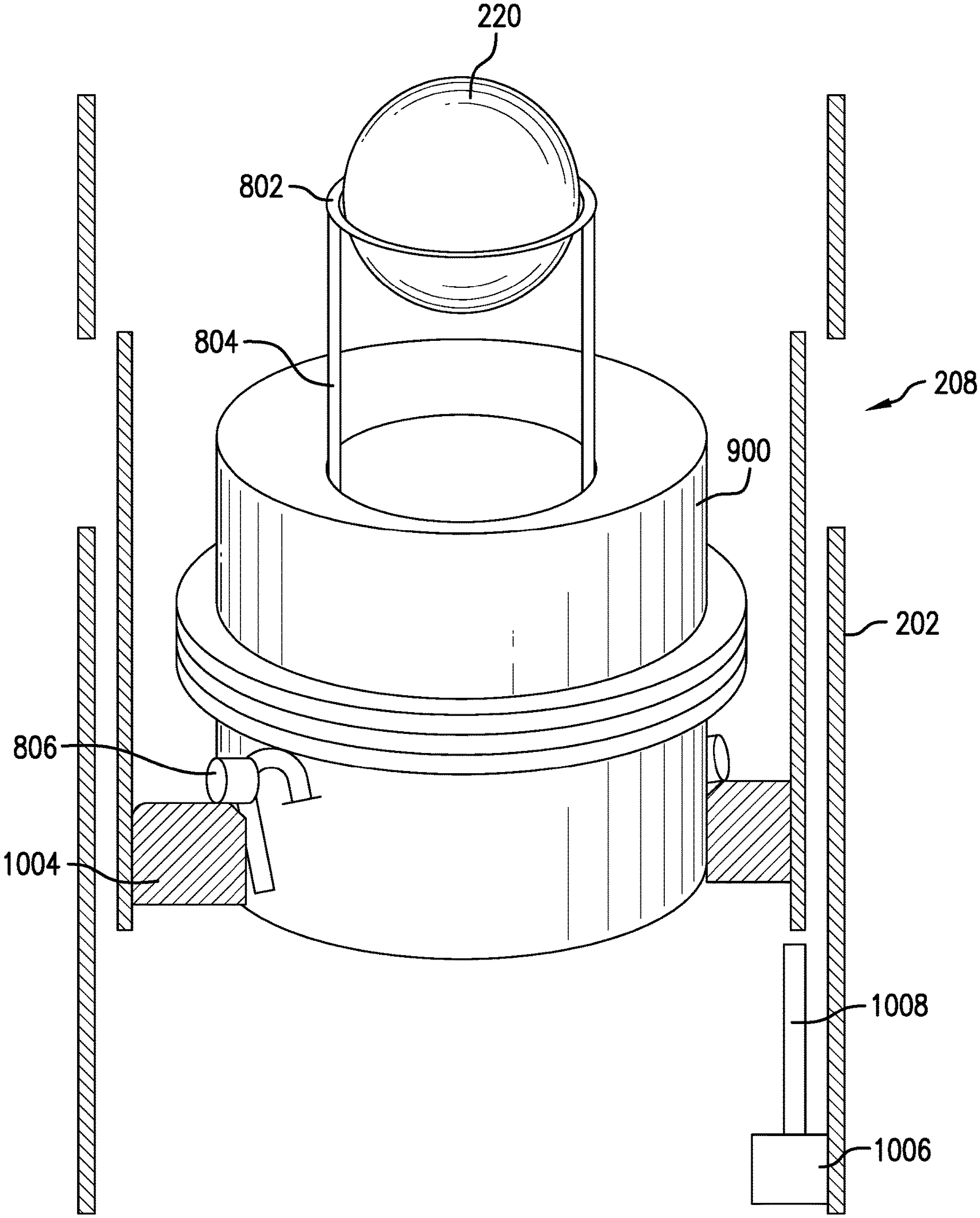


FIG. 11

SHEARABLE SPLIT BALL SEAT

BACKGROUND

In the resource recovery industry, formation fracturing ("fracking") is used to increase a hydrocarbon output from a reservoir by introducing fracking fluid from a production string into the reservoir. The production string includes a port and a frac sleeve that opens and closes the port to control flow of frac fluid into the reservoir. The frac sleeve includes a tubular passage with a ball seat therein. A ball is dropped through the production string to land on the ball seat, thereby blocking a fluid passage through the frac sleeve. Fluid pressure can be then applied to the ball and ball seat in order to move the frac sleeve axially from a closed position, thereby opening the port. When desired, a disintegrating fluid is pumped downhole to dissolve the ball, thereby releasing the fluid pressure on the frac sleeve, allowing the frac sleeve to move back to its closed position, thereby closing the port. A problem that occurs during ball dissolution is that the ball can become cemented into the ball seat, thereby preventing closure of the port as desired. Accordingly, there is a need for a ball seat that allows for the ball to pass through the ball seat without cementation.

SUMMARY

In one embodiment, a frac sleeve assembly is disclosed, the frac sleeve assembly including a ball seat having a first half and a second half, wherein the first half and the second half are matable to cooperatively retain a frac ball at the ball seat; and a sleeve within which the ball seat moves, the sleeve including a profile configured to separate the first half and the second half to allow passage of the frac ball through the ball seat.

In another embodiment, a method of operating a frac assembly is disclosed. A frac ball is received at a ball seat including a first half and a second half, wherein the first half and the second half are matable to cooperatively retain the frac ball at the ball seat. The ball seat moves against a profile to separate the first half and the second half to allow passage of the frac ball through the ball seat.

In yet another embodiment, a frac sleeve assembly is disclosed. The frac sleeve assembly includes a ball seat having a ridge for receiving a ball, and a slot; a ring assembly including a ring and an associated shifting pin that extends through the slot; and a sleeve within which the ball seat moves, the sleeve having a protrusion that selectively engages the shifting pin to move the ring with respect to the ridge of the ball seat to release the ball from the ball seat.

In yet another embodiment, a method of operating a frac sleeve assembly is disclosed. A ball is received at a ridge of a ball seat of the frac sleeve assembly, wherein the ball seat includes slot and a ring assembly, and the ring assembly includes a ring and an associated shifting pin that extends through the slot. The ball seat moves within a sleeve having a protrusion in order to engage the protrusion with the shifting pin to move the ring with respect to the ridge of the ball seat to release the ball from the ball seat.

BRIEF DESCRIPTION OF THE DRAWINGS

The following descriptions should not be considered limiting in any way. With reference to the accompanying drawings, like elements are numbered alike:

FIG. **1** shows an illustrative production system;

FIG. **2** shows a detailed diagram of an illustrative frac assembly of the production system of FIG. **1** in various embodiments;

FIG. **3** shows a ball seat in one embodiment;

FIG. **4** shows a frac sleeve assembly including the ball seat of FIG. **3**;

FIG. **5** shows a second operating stage of a frac assembly in which the port of a housing of the frac assembly is opened;

FIG. **6** shows a third operating stage of the frac assembly in which the ball seat is fractured;

FIG. **7** shows a fourth operating stage in which the frac sleeve assembly is returned to its first position;

FIG. **8** shows side and front view of a ring assembly for use in another ball seat embodiment;

FIG. **9** shows a ball seat suitable for use with the ball seat ring assembly of FIG. **8**;

FIG. **10** shows a frac sleeve assembly including the ball seat of FIG. **9** arranged within a sleeve; and

FIG. **11** shows the ball seat having moved axially through the sleeve to engage a protrusion to a shifting pin of the ring assembly.

DETAILED DESCRIPTION

A detailed description of one or more embodiments of the disclosed apparatus and method are presented herein by way of exemplification and not limitation with reference to the Figures.

Referring to FIG. **1**, an illustrative production system **100** is shown. The production system **100** includes a production string **102** extending from a rig **104** located at a surface location **106**. The production string **102** extends through a wellbore **108** penetrating a formation **110** and a reservoir **112** in the formation **110**. A fracture ("frac") assembly **114** is disposed on the production string **102** at a location in the reservoir **112** for the purposes of fracking the reservoir **112**. The frac assembly **114** is disposed between a first section **102*a*** of the production string **102** and a second section **102*b*** of the production string **102**. A second frac assembly **124** can be disposed at a lower end of the second section **102*b***. Additional frac assemblies (not shown) can also be disposed at lower sections of the production string **102**. As shown in FIG. **1**, the wellbore **108** can deviate to have a horizontal section **108*b*** and the production string **102** can deviate along with the wellbore **108** to extend through the horizontal section **108*b***. One or more of the frac assemblies (such as second frac assembly **124**) can be disposed within the horizontal section.

In order to perform a frac operation, a frac fluid **120** is pumped from a frac fluid storage device **116** through delivery pipe **118** and down through the production string **102** to exit the frac assembly **114** into the reservoir **112**. In various embodiments, various perforations **128** can be previously formed in the reservoir **112** through which the frac fluid **120** passes into the reservoir **112**. Proppant entrained in the frac fluid **120** is carried into the perforations **128** in order to prop the perforations **128** open, thereby allowing for increased hydrocarbon recovery from the reservoir **112**. As discussed below with respect to FIG. **2**, the frac assembly **114** includes elements that can be moved therein in order to control the frac operation by opening a port to release the frac fluid **120** into the reservoir **112** and by closing the port to stop the flow of frac fluid **120** into the reservoir **112**.

FIG. **2** shows a detailed diagram of an illustrative frac assembly **114** of the production system **100** in various embodiments. The frac assembly **114** includes a housing **202** coupled to the production string **102**. The housing **202** includes an inlet **204** at an intersection of the housing **202** and the first section **102***a* of the production string **102**. The housing **202** also includes an outlet **206** at an intersection of the housing **202** and the second section **102***b* of the production string **102**. The housing **202** further includes one or more ports **208** on the side of the housing **202** for delivery of frac fluid **120** from the frac assembly **114** into the reservoir **112**. The ports **208** can be opened or closed based on a position of a frac sleeve assembly **210**.

The frac sleeve assembly **210** includes a sleeve **212** and a ball seat **214** that define a fluid passage **215** through the frac sleeve assembly **210**. The frac sleeve assembly **210** can move between a first position and a second position. The first position is relatively closer to the inlet **204** than the second position. When the frac sleeve assembly **210** is in the first position, the sleeve **212** covers a port **208** of the frac assembly **114**, thereby closing the port **208**. When the frac sleeve assembly **210** is in the second position, the sleeve **212** is away from the port **208**, thereby opening the port **208**. The port **208** can be a plurality of ports in various embodiments.

Fluid can pass from the inlet **204** to the outlet **206** by passing through the frac sleeve assembly **210**. The frac sleeve assembly **210** can be moved from the first position to the second position by dropping a ball **220** into the production string **102** at the surface and allowing the ball **220** to settle onto the ball seat **214**, thereby blocking the flow of fluid from the inlet **204** to the outlet **206**. The frac fluid **120** entering the frac assembly **114** from the inlet **204** then applies a fluid pressure on the ball **220**, forcing the frac sleeve assembly **210** to move towards the outlet **206** as indicated by arrows **225** (i.e., into the second position). In various embodiments, the frac sleeve assembly **210** is originally secured to the housing **202** via shear screws (not shown) and the fluid pressure is applied above a breaking threshold for the shear screws. Once the shear screws are broken, the frac sleeve assembly **210** moves toward the outlet **206** under fluid pressure and uncovers ports **208**, allowing the frac fluid **120** to flow out of the housing **202** via the port **208** and into the reservoir **112**. The port **208** is closed by moving the frac sleeve assembly **210** toward the inlet **204** (i.e, back to the first position). In various embodiments, the frac sleeve assembly **210** is moved toward the inlet **204** by disintegrating or dissolving the ball **220**, thereby relieving the downward pressure of the fluid on the ball seat **214** and frac sleeve assembly **210**. A biasing device **230** such as a spring provides a force directed toward inlet **204***a* in order to return the frac sleeve assembly **210** to its original position in which it covers, and thereby closes, port **208**. In an alternate embodiment, the biasing device **230** can be replaced with a lock that allows the frac sleeve assembly **210** to be locked into the open position.

In order to disintegrate the ball **220**, a disintegrating fluid is pumped down the production string to the ball **220**. The disintegrating fluid can be the frac fluid. The ball **220** is designed to disintegrate when exposed to the disintegrating fluid at a selected temperature. In general, the disintegrating fluid that forces the ball **220** into the ball seat **214** is provided into the production string **102** at a temperature (e.g., about 100° Celsius) below a reaction temperature for the ball **220** and the disintegrating fluid. Over time, the temperature of the disintegrating fluid rises to thermal equilibrium with the downhole temperature. At the downhole temperature, the disintegrating fluid chemically interacts with the ball **220** in order to disintegrate the ball **220**. The disintegration process is designed to reduce the size of the ball **220**, allowing the ball **220** to pass through the ball seat **214**, thereby relieving the pressure from the frac sleeve assembly **210** and allowing the frac sleeve assembly **210** to return to its original position. The ball seat can also be locked into an open position

During dissolution, the ball **220** can become cemented into position in the ball seat **214**, making it difficult for the fluid passage of the ball seat to be opened up, thereby preventing closure of the port **208**. Embodiments discussed below provide methods for ensuring removal of the ball **220** from the ball seat **214** and closure of port **208**.

FIG. **3** shows a ball seat **300** in one embodiment. The ball seat **300** includes a first half **302** and a second half **304** formed by a split **306** that defines an axially-extending plane. The first half **302** mates to the second half **304** to form the ball seat **300**. The assembled ball seat **300** includes a first end **308** proximate the inlet and a second end **310** proximate the outlet. The first end **308** includes a funnel section **320** with a ridge **322**. The ridge **322** captures a frac ball dropped into the funnel section **320**. One or more shear screws **312** secure the first half **302** and the second half **304** together. The first half **302** and second half **304** include recessed regions at the second end **310**. When the first half **302** is mates to the second half **304**, the recess regions form a notch **314** at the split **306**.

FIG. **4** shows a frac sleeve assembly **400** including the ball seat **300** of FIG. **3**. The frac assembly **400** is shown within a housing **202** of a frac assembly in a first operating stage in which the frac sleeve assembly **400** covers port **208** of the housing **202**. The frac sleeve assembly **400** moves axially within the housing **202**. The frac sleeve assembly **400** includes a sleeve **402** and the ball seat **300** of FIG. **3**. The ball seat **300** is capable over moving axially within the sleeve **402**. A frac sleeve shear pin **412** maintains the frac sleeve assembly **400** in a first position within the housing **202** to cover port **208**. A structure **406** supports biasing member **408** to provide a force in a direction of the inlet to the housing **202**. A ball seat shear pin **410** maintains the ball seat **300** at a selected location within the sleeve **402**.

FIG. **5** shows a second operating stage in which the port **208** of the housing **202** is opened. A frac ball **220** is dropped into the housing **202** and is seated at the ridge **322** of the ball seat **300**. The ball **220** blocks the fluid passage through the ball seat **300**. Consequently, a build-up of fluid pressure at the first end of the ball seat **300** breaks the frac sleeve shear pin **412** and moves the frac sleeve assembly **400** towards the outlet, thereby compressing the biasing member **408** and opening port **208**.

FIG. **6** shows a third stage in which the ball seat **300** is fractured. The fluid pressure is increased to break the ball seat shear pin **410**. With the ball seat shear pin **410** broken, the ball seat **300** moves axially within sleeve **402** to engage the notch **314** with the profile **404**, thereby breaking shear screws **312** and splitting the ball seat **300** into its two halves, i.e., first half **302** and second half **304**. Once ball seat **300** is split, ball **220** passes through the ball seat **300**, thereby opening up the fluid passage **215** in the ball seat **300**.

FIG. **7** shows a fourth stage in which the frac sleeve assembly **400** is returned to its first position. With the fluid passage in the ball seat **300** open, the fluid pressure is removed or reduced. The biasing member **408** thus provides the dominant force on the frac sleeve assembly **400**, pushing the frac sleeve assembly **400** back into the first position at which location the frac sleeve assembly **400** closes the port **208**.

FIG. **8** shows side and front view of a ring assembly **800** for use in another ball seat embodiment. The ring assembly **800** includes a ring **802** and at least one arm **804** extending from a section of the ring **802**. The at least one arm **804** includes a shifting pin **806**. In various embodiments, the ring assembly **800** includes two arms **804** on radially opposite locations of the ring. Each of the arms **804** includes a shifting pin **806**.

FIG. **9** shows a ball seat **900** suitable for use with the ball seat ring assembly **800** of FIG. **8**. The ring **802** of the ring assembly **800** resides at a ridge **902** of the ball seat **900**. The arms **804** of the ring assembly **800** extend through the interior fluid passage of the ball seat **900** and the shifting pins **806** extends through respective slots **904** in a wall of the ball seat **900**. In various embodiments, the slot **904** is a J-slot.

FIG. **10** shows a frac sleeve assembly **1000** including the ball seat **900** arranged within a sleeve **1002**. The frac sleeve assembly **1000** is slidable within housing **202** having port **208**. A ball **220** is shown lodged at the ring **802** located at the ridge **902** of the ball seat **900**. As a result the frac sleeve assembly **1000** has traveled axially with the housing **202** to open port **208**. The ball seat **900** is slidably engaged within a sleeve **1002** of the frac sleeve assembly **1000**. An inner surface of the sleeve **1002** includes a protrusion **1004**, which can be one or more protrusions. In FIG. **10**, the protrusion **1004** has not engaged the shifting pin **806**. Since the ball **220** is lodged in the ring **802**, the fluid passage **215** of the ball seat **900** is blocked, causing an increase in fluid pressure above the ball seat **900**. The increased fluid pressure forces the ball seat **900** axially through sleeve **1002** to engage the protrusion **1004** to the shifting pin **806**, as shown in FIG. **11**.

FIG. **11** shows the ball seat **900** having moved axially through the sleeve **1102** to engage the protrusion **1004** with the shifting pin **806**. The protrusion **1004** prevents further axial motion of the ring assembly **800** in the direction of the protrusion **1004**. As the ball seat **900** traverse the axial location of the protrusion **1004**, the ring assembly **800** and ball **220** are held in place by the protrusion **1004**, thereby disengaging the ball **220** from the ridge **902** and opening the fluid passage. With the fluid passage upon, the biasing member forces the frac sleeve assembly back into position over the port **208**. The ball **220** can be further disintegrated by a disintegrating fluid. Upon disintegration, the ball passes through the ring **802** and the ball seat **900**.

Set forth below are some embodiments of the foregoing disclosure:

Embodiment 1

A frac sleeve assembly. The frac sleeve assembly includes a ball seat and a sleeve within which the ball seat moves. The ball seat has a first half and a second half, wherein the first half and the second half are matable to cooperatively retain a frac ball at the ball seat. The sleeve includes a profile configured to separate the first half and the second half to allow passage of the frac ball through the ball seat.

Embodiment 2

The frac sleeve assembly of any prior embodiment, wherein the first half and the second half are separated by a split defining an axially-extending plane.

Embodiment 3

The frac sleeve assembly of any prior embodiment, wherein the combined first half and second half form a notch configured to receive the profile when the ball seat moves with respect to the sleeve.

Embodiment 4

The frac sleeve assembly of any prior embodiment, further comprising shear screws for retaining the first half to the second half.

Embodiment 5

A method of operating a frac assembly. The method includes receiving a frac ball at a ball seat comprising a first half and a second half, wherein the first half and the second half are matable to cooperatively retain the frac ball at the ball seat; and moving the ball seat against a profile to separate the first half and the second half to allow passage of the frac ball through the ball seat.

Embodiment 6

The method of any prior embodiment, wherein the first half and the second half are separated by an axially-extending plane.

Embodiment 7

The method of any prior embodiment, further comprising moving the ball seat to receive the profile at a recess formed in the ball seat.

Embodiment 8

The method of any prior embodiment, wherein shear screws secure the first half to the second half via shear screws, further comprising breaking the shear screws by moving the ball seat against the profile.

Embodiment 9

A frac sleeve assembly. The frac sleeve assembly includes a ball seat, a ring assembly and a sleeve within which the ball seat moves. The ball seat includes a ridge for receiving a ball, and a slot. The ring assembly includes a ring and an associated shifting pin that extends through the slot. The sleeve has a protrusion that selectively engages the shifting pin to move the ring with respect to the ridge of the ball seat to release the ball from the ball seat.

Embodiment 10

The frac sleeve assembly of any prior embodiment, wherein the slot is a J-slot.

Embodiment 11

The frac sleeve assembly of any prior embodiment, wherein the ball seat moves axially within the sleeve to engage the shifting pin to the protrusion.

Embodiment 12

The frac sleeve assembly of any prior embodiment, wherein the ring is located at the ridge when the shifting pin is not engaged with the protrusion and wherein engaging the protrusion with the shifting pin to move the shifting pin through the slot moves the ring axially away from the ridge.

Embodiment 13

A method of operating a frac sleeve assembly. The method includes receiving a ball at a ridge of a ball seat of the frac sleeve assembly, the ball seat including a slot and a ring assembly, the ring assembly including a ring and an associated shifting pin that extends through the slot; and moving the ball seat within a sleeve having a protrusion in order to engage the protrusion with the shifting pin to move the ring with respect to the ridge of the ball seat to release the ball from the ball seat.

Embodiment 14

A method of any prior embodiment, wherein the slot is a J-slot.

Embodiment 15

A method of any prior embodiment, wherein the ring is located at the ridge when the shifting pin is not engaged with the protrusion and wherein engaging the protrusion with the shifting pin to move the shifting pin through the slot moves the ring axially away from the ridge.

The use of the terms "a" and "an" and "the" and similar referents in the context of describing the invention (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. Further, it should be noted that the terms "first," "second," and the like herein do not denote any order, quantity, or importance, but rather are used to distinguish one element from another. The modifier "about" used in connection with a quantity is inclusive of the stated value and has the meaning dictated by the context (e.g., it includes the degree of error associated with measurement of the particular quantity).

The teachings of the present disclosure may be used in a variety of well operations. These operations may involve using one or more treatment agents to treat a formation, the fluids resident in a formation, a wellbore, and/or equipment in the wellbore, such as production tubing. The treatment agents may be in the form of liquids, gases, solids, semi-solids, and mixtures thereof. Illustrative treatment agents include, but are not limited to, fracturing fluids, acids, steam, water, brine, anti-corrosion agents, cement, permeability modifiers, drilling muds, emulsifiers, demulsifiers, tracers, flow improvers etc. Illustrative well operations include, but are not limited to, hydraulic fracturing, stimulation, tracer injection, cleaning, acidizing, steam injection, water flooding, cementing, etc.

While the invention has been described with reference to an exemplary embodiment or embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the claims. Also, in the drawings and the description, there have been disclosed exemplary embodiments of the invention and, although specific terms may have been employed, they are unless otherwise stated used in a generic and descriptive sense only and not for purposes of limitation, the scope of the invention therefore not being so limited.

What is claimed is:

1. A frac sleeve assembly, comprising:

a ball seat having a ridge for receiving a ball, and a slot;

a ring assembly comprising a ring and an associated shifting pin that extends through the slot; and

a sleeve within which the ball seat moves, the sleeve having a protrusion that selectively engages the shifting pin to move the ring with respect to the ridge of the ball seat to release the ball from the ball seat,

wherein the ring is located at the ridge when the shifting pin is not engaged with the protrusion and wherein engaging the protrusion with the shifting pin to move the shifting pin through the slot moves the ring axially away from the ridge.

2. The frac sleeve assembly of claim **1**, wherein the slot is a J-slot.

3. The frac sleeve assembly of claim **1**, wherein the ball seat moves axially within the sleeve to engage the shifting pin to the protrusion.

4. A method of operating a frac sleeve assembly, comprising:

receiving a ball at a ridge of a ball seat of the frac sleeve assembly, the ball seat includes slot and a ring assembly, the ring assembly comprising a ring and an associated shifting pin that extends through the slot; and

moving the ball seat within a sleeve having a protrusion in order to engage the protrusion with the shifting pin to move the ring with respect to the ridge of the ball seat to release the ball from the ball seat;

wherein the ring is located at the ridge when the shifting pin is not engaged with the protrusion and wherein engaging the protrusion with the shifting pin to move the shifting pin through the slot moves the ring axially away from the ridge.

5. The method of claim **4**, wherein the slot is a J-slot.

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